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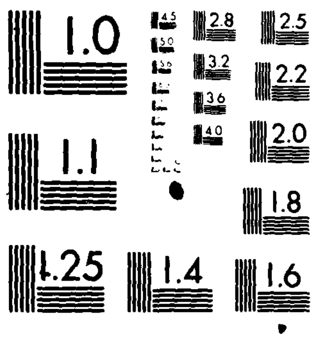

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The piezobirefringence of calcium fluoride, barium fluoride, strontium fluoride, galium arsenide, and cadmium fluoride has been measured in the infrared over the wavelength range 3.5 to 11 micrometers. A large dispersion was found in the coefficients of the fluorides; moreover, some fo the coefficients were observed to reverse sign. The data for GaAs showed a small yet significant dispersion. The data for the alkaline-earth fluorides were fitted to a three parameter strain -dependent oscillator representation of the infrared-active tranverse-optic (TO)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) photon; the predominant contribution to the dispersion comes from the strain-induced TO phonon splitting; estimates were made to the strain-induced oscillator strength anisotropy. The GaAs data were fitted to the same model but with only two free parameters; here the predominant contribution to the dipersion came from the estimated strain-induced oscillator strength anisotropy of the TO phonon; the experimental data agree fairly well with the theory of Humphreys and Maradudin. The absolute piezo-optic constants have also been obtained at discrete laser wavelengths for the fluorides.

FINAL TECHNICAL REPORT

OPTICAL PROPERTIES OF MATERIAL FOR THE INFRARED

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FINAL TECHNICAL REPORT
OPTICAL PROPERTIES OF MATERIAL FOR THE INFRARED

1. ABSTRACT

The piezobirefringence of calcium fluoride, barium fluoride, strontium fluoride, galium arsenide, and cadmium fluoride has been measured in the infrared over the wavelength range 3.5 to 11 micrometers. A large dispersion was found in the coefficients of the fluorides; moreover, some of the coefficients were observed to reverse sign. The data for GaAs showed a small yet significant dispersion. The data for the alkaline-earth fluorides were fitted to a three parameter strain-dependent oscillator representation of the infrared-active tranverse-optic (TO) photon; the predominant contribution to the dispersion comes from the strain-induced TO phonon splitting; estimates were made to the strain-induced oscillator strength anisotropy. The GaAs data were fitted to the same model but with only two free parameters; here the predominant contribution to the dispersion came from the estimated strain-induced oscillator strength anisotropy of the TO phonon; the experimental data agree fairly well with the theory of Humphreys and Maradudin. The absolute piezo-optic constants have also been obtained at discrete laser wavelengths for the fluorides.

The prism coupler method, based on m-line spectroscopy, has been utilized to measure the refractive index and thickness of a mixed film of magnesium oxide and silicon dioxide prepared by coevaporation. The index data agreed well with the Drude model of refractive index; due to the high precision of the method one could observe a significant birefringence in the film, a sign of large internal strain. An intercomparison of six methods of thin film thickness measurement was made on the basis of reports in the literature and measurements performed at this laboratory.

Key Words: Anisotropy; BaF_2; birefringence; CaF_2; CdF_2; dispersion; infrared; MgO; oscillator strength; phonon; photoelastic; piezo-birefringence; piezo-optic; prism coupler; refractive index; SiO_2; SrF_2; strain; stress; thickness; thin film; tranverse-optic phonon

2. OBJECTIVES

2.1 To measure the effect of stress on the refractive index of optical materials in the infrared region of the spectrum in order to calculate the photoelastic constants which are to be interpreted on the basis of models for the stress dependence of the infrared lattice absorption bands.

2.2 To develop methods for characterizing propagation and attenuation in thin films, and, in particular, the prism coupler method. Also, to determine the feasibility of a new opto-acoustic technique for studying low level absorption in transparent dielectric films.

3. STATUS REPORT

3.1 Piezo-optics

The main emphasis of the work performed has been concerned with Objective 2.1. This is because relatively few piezo-optic measurements have been made at wavelengths beyond 2.5 μm and most of these data are at discrete laser wavelengths. With so few data it becomes difficult to test any of the theories that have been developed for predicting photoelastic dispersion due to the effect of strain on the infrared-active transverse-optic (TO) phonon.[1] This is in contrast to the relative success of fitting piezo-optic data to strain-induced electronic effects such as the effect of strain on the energy bands and free carriers of semiconductors[2]. Only recently have piezo-optic measurements been made at a significant number of wavelengths[3,4] and most of these measurements have been made at this laboratory. In this report we discuss piezo-optic measurements we have made on CaF_2, BaF_2, SrF_2, GaAs, and CdF_2 and some of their theoretical implications. Almost all of these materials are technologically important as infrared transmitting materials.

Specimens of CaF_2, BaF_2 and SrF_2 were prepared from single crystal material obtained from a commercial supplier. Two specimens of each material were prepared in the form of rectangular prisms 1.2 x 1.2 x 3.6 cm. The specimens were oriented by Laue X-ray diffraction; one specimen was oriented with the long axis along the [100] crystallographic axis, the other was oriented with the long axis along the [111] axis. Orientation was estimated to be accurate to within 1°. Two opposite faces of each specimen were commercially polished sufficiently parallel so that several Fizeau interference fringes could be observed upon observation in collimated coherent light.

In our earliest work[4] we reported on room temperature measurements of all the piezo-optic constants q_{11}, q_{12}, and q_{14} of CaF_2, BaF_2 and SrF_2 at the discrete laser wavelengths 0.6328 μm, 1.15 μm and 3.39 μm. The measuremnts were performed by a combination of Fizeau, Twyman-Green and polarimetric techniques using helium-neon lasers as sources. All measurements were performed by application of static uniaxial stresses to the specimens.

In a later work[5], we extended the piezo-birefringence measurements further into the infrared because we expected to observe significant dispersion due to the close wavelength proximity of the infrared-active transverse-optic (IRTO) phonons. The piezo-birefringence coefficients $q_{11}-q_{12}$ and q_{44} of CaF_2, BaF_2 and SrF_2 were measured at room temperature at nine wavelengths in the range 3.4 to 10.6 μm by a static stress method. Because the retardations at these wavelengths are small, we developed a modified compensator technique to perform the measurements. A CO_2 laser, a grating monochromator and spectral filters were employed as the light sources and pyroelectric, InSb and PbSnTe detectors were employed. On the basis of these measurements a large dispersion was found in the piezo-optic coefficients; in fact we observed a sign reversal in the q_{44} coefficients of CaF_2 and SrF_2.

From the piezo-optic constants $q_{11}-q_{12}$ and q_{44} we calculated the photoelastic constants $k_{11}-k_{12}$ and k_{44} which are directly related to the strain dependence of the dielectric tensor ε_{ij}. From plots of $k_{11}-k_{12}$ and k_{44} as a function of frequency two effects could be observed: 1) The values of the high frequency constants $k_{11}^{\infty} - k_{12}^{\infty}$ and k_{44}^{∞} are of opposite sign and vary very little from material to material. 2) The magnitudes of both $k_{11}-k_{12}$ and k_{44} decrease with increasing wavelength with the largest changes occurring in the materials with the highest IRTO phonon frequencies. The data were fitted to a three parameter oscillator model based on the strain dependence of the IRTO phonon frequency and oscillator strength. Most recently, a detector has become available that is more sensitive in the wavelength range 5.5 to 11 μm. We therefore decided to repeat the piezo-birefringence measurements at more wavelengths in this range. The results were generally in good agreement with our earlier measurements. All the data have been fit to an improved model of piezo-birefringence originally presented by Humphreys and Maradudin[1] (HM) and subsequently by Bendow, Gianino, Tray, and Mitra[7] (BGTM). We find that the principal contribution to the dispersion comes from the strain-induced splitting of the IRTO mode. Estimates have been made of the strain-induced relative anisotropy of the transverse effective charge. Although the data can be fit to the basic phenomenological model of HM, no microscopic theoretical calculations are available to compare with the computed parameters. Such calculations have been made for GaAs and, hence, similar measurements have been conducted on GaAs.

Crystalline slices of high resistivity (4.3×10^7 Ω cm) GaAs were provided by Don Hobgood of the Westinghouse Research Center. The slices were approximately 8 cm in diameter by 1 cm thick. These slices were examined for internal strain in both an infrared polarimeter and in an infrared polarizing microscope. The information was supplied to Westinghouse on a confidential basis. In turn, we prepared specimens for piezo-birefringence studies from these slices. We oriented the crystal slices by X-ray Laue diffraction. Two specimens were prepared, one oriented for stress along the [001] crystal axis with propagation of radiation along [100]; the other was oriented for stress along the [011] axis with propagation along [100]. Specimens were approximately 1 x 1 x 3 cm prismatic bars.

The piezo-birefringence of the two specimens was measured over the wavelength range 3.5 μm to 10.6 μm by a variety of polarimetric techniques. A monochromator and an InSb detector were used in the range 3.5 to 5.4 μm. A filter wheel and PbSnTe detector were used between 5.4 μm and 9.3 μm; a CO_2 laser and pyroelectric detector were used between 9.3 μm and 10.6 μm. The piezo-birefringence constants $q_{11}-q_{12}$ and q_{44}, the elasto-optic constants $p_{11}-p_{12}$ and p_{44}, the photoelastic constants $k_{11}-k_{12}$ and k_{44} and the piezo-dielectric constants $d_{11}-d_{12}$ and d_{44} were computed. It was found that $k_{11}-k_{12}$ and k_{44} had a small yet significant dispersion over the specified wavelength range. A two parameter least squares fit of $k_{11}-k_{12}$ and k_{44} has been made to the basic phenomenological expression of HM; the strain-dependent splittings of the tranverse-optic (TO) mode measured by Weinstein and Cardona[8] were used as input parameters. The computed coefficients were the strain-induced anisotropy of the oscillator strength and the high frequency photoelastic constants $k_{11}^{\infty} - k_{12}^{\infty}$ and k_{44}^{∞}, which were in good agreement with extrapolations of electronic photoelastic dispersion measurements[9]. From the induced oscillator-strength anisotropy, we computed the strain-induced relative anisotropy of the transverse effective-charge. In the region of measurement, the dispersion comes predominantly from the effective charge anisotropy, with a negligible contribution from the splitting of the TO phonon frequency.

Because if the similarity of the infrared absorption spectrum of CdF_2 with that of CaF_2, we decided to measure the infrared piezo-birefringence of CdF_2. Crystals of CdF_2 were purchased from a commercial supplier. Two specimens were prepared from these crystals, one oriented for stress along the [001] crystal axis, the other for stress along the [111] crystal axis. The [001] specimen was a rectangle prism approximately 6 x 7 x 17 mm; the [111] specimen was a rectangular prism approximately 8 x 8 x 22 mm.

The refractive index of CdF_2 was measured at 9 wavelengths in the visible and at 1.15 μm by means of a V-block refractometer. The data were fitted to a power law expression of the form $n^2 = A\lambda^2 + B + C\lambda^{-2} + D\lambda^{-4} + E\lambda^{-6} + F\lambda^{-8}$, with a standard deviation of 1.4×10^{-4}. A fit to the above equation was also obtained by eliminating the point at 1.15 μm; the coefficients changed in value and the resultant standard deviation was 7×10^{-5}. The measured values differed by 0.0005 from values reported in the literature[10]; this difference is attributed to differences in crystal purity.

The piezo-optic constants q_{11}, q_{12}, and q_{44} have been measured in the visible at 0.6328 μm by means of Fizeau interferometry and polarimetry. In the infrared the piezo-birefringence coefficients $q_{11}-q_{12}$ and q_{44} have been measured over the wavelength range 3.5 to 11 μm. The coefficients show a considerable dispersion in the infrared which follows closely the dispersion of the corresponding coefficients of CaF_2.

3.2 Propagation and Attenuation in Thin Films

Work has been started for characterizing propagation and attenuation in thin films. Although we originally intended to explore the presence of H_2O in thin films by means of opto-acoustic spectroscopy, we were unable to obtain a color center laser which emits in the region of interest. Instead, we have addressed the use of the prism coupler method for characterizing thin films.

The refractive index and thickness of a film prepared by coevaporation (79% Mgo, 21% SiO_2 by volume) was measured by the prism coupler method. Measurements of the transverse electric (TE) and transverse magnetic (TM) mode coupling angles were made at three wavelengths of the argon-ion laser[11]. Computer programs were developed for fitting the prism coupler data to the thin film mode propagation equations in order to calculate the refractive index and thickness of the film. The prism coupler method is a very precise means for obtaining the refractive index of thin films[12]. Thus we were able to measure dispersion in the refractive index; furthermore, the accuracy was sufficient to measure a birefringence on the film which we attributed to internal stresses. A signature for the birefringence was observed in the m-line spectrum of the film, in which the order of the TE_0 and TM_0 modes was interchanged as compared to their expected order in an isotropic film. The measured values of refractive index agreed extremely well with a Drude model calculation based on the estimated volume fraction of each of the film constituents.

An intercomparison of techniques for measuring the thicknesses of films ~1 μm was made[13]. It was based on measurements reported in the literature and also measurements conducted at the National Bureau of Standards. Six techniques were compared, stylus profiling, dual beam interferometry, multiple beam interferometry, prism-coupler method, ellipsometry, and channeled spectra. All of the techniques are of comparable accuracy; dual beam interferometry and stylus profiling have a conservative accuracy of 2.5% for 1 μm thick films; ellipsometry, channeled spectra and the prism coupler method are accurate to about 1 percent; multiple beam interferometry is accurate to about 0.5 percent. The stylus instrument and the dual and multiple beam interferometry require the presence of a step; dual beam and multiple interferometry require an opaque, reflecting specimen; the prism coupler method, ellipsometry, and channeled spectra require transparent specimens; stylus profiling and the prism coupler require contact with the specimen.

4. CUMMULATIVE PUBLICATIONS

A. Feldman and T. Vorburger
"A Comparison of Optical and Mechanical Methods of Thickness Measurement" (to be published in the Proceedings of the SPIE)

A. Feldman and E. N. Farabaugh
"Index, Thickness and Birefringence of Thin Films by Guided Waves" (to be published in Laser Induced Damage in Optical Materials: 1981)

A. Feldman and R. M. Waxler
"Dispersion of the Piezobirefringence of GaAs Due to Strain-Dependent Lattice Effects"
J. Appl. Phys. 53, 1477 (1982).

A. Feldman
"The Photoelastic Effect in Optical Materials"
in Basic Optical Properties of Materials Summaries of Papers, NBS Special Publication 574, A. Feldman, ed. (USGPO, Washington, 1980), pp. 204-208

A. Feldman and R. M. Waxler
"Strain-Induced Splitting and Oscillator Strength Anisotropy of the Infrared Transverse-Optic Phonon in Calcium Fluoride, Strontium Fluoride, and Barium Fluoride"
Phys. Rev. Lett. 45, 126 (1980)

R. M. Waxler, A. Feldman, and D. Horowitz
"Piezo-Optic Coefficients of Some Neodymium Doped Laser Glasses and Single Crystals of CaF_2, BaF_2, and SrF_2"
in Laser Induced Damage in Optical Materials: 1978
NBS Special Publication 541, A. J. Glass and G. H. Guenther, eds. (USGPO, Washington, 1979), pp. 30.

A. Feldman, D. Horowitz, R. M. Waxler, and M. J. Dodge
"Optical Materials Characterization"
Final Technical Report, February 1, 1978-September 30, 1978
NBS Technical Note 993 (USGPO, Washington, 1979)

A. Feldman, R. M. Waxler, and L. Grabner
"Dispersion of the Piezo-birefringence of CaF_2, SrF_2 and BaF_2 Due to Strain Dependent Lattice Effects"
(in preparation)

A. Feldman, D. Horowitz, R. M. Waxler, and L. Grabner
"Piezo-optic, Thermo-optic, and Thermal Expansion Coefficients of CaF_2"
(in preparation)

5. INTERACTIONS

5.1 Topical Conference on Basic Optical Properties of Materials

Albert Feldman was chairman of the organizing committee and the program committee. (See Appendix for conference description)

5.2 Committee Work

5.2.1 American Society for Testing and Materials

Albert Feldman is editor for ASTM subcommittee F1.02 on Lasers. This subcommittee is part of Committee F1 on Electronics. The subcommittee is concerned with writing standards for testing optical components to be used in laser systems. The work on the subcommittee has strong support from the Air Force. Many of the active committee members are employed by the Air Force or work under contract for the Air Force. These include Arthur H. Guenther, Chief Scientist of the Air Force Weapons Center at Kirtland AFB, and the subcommittee chairman, John Detrio, of the University of Dayton Research Institute.

5.2.2 Optical Society of America

Albert Feldman is a member of the committee on standards for the Optical Society of America.

5.3 Talks Presented

"Piezo-Optical Coefficients of Some Neodymium Laser Glasses and Single Crystals of CaF_2, BaF_2, and SrF_2" presented at the Boulder Damage Symposium, Boulder, CO, September 1979.

Invited Talk: "The Photoelastic Effect in Optical Materials" given at the Topical Conference on Basic Optical Properties of Materials by A. Feldman.

"Strain-Induced Splitting of the Transverse Optic Phonon in CaF_2, BaF_2, and SrF_2"
Bull. Amer. Phys. Soc. 25, 418 (1980)
Talk given at APS March Meeting.

Invited Talk: "Optical Properties of Thin Films," Division Seminar, Ceramics, Glass and Solid State Science Division, NBS, February 1980, by A. Feldman.

"Lattice Contribution to the Dispersion of the Piezo-birefringence of GaAs," A. Feldman and R. M. Waxler, J. Opt. Soc. Am. 71, 1619 (1981). Presented at the Annual Meeting of the Optical Society of America, October 29, 1981, by A. Feldman.

"Index, Thickness, and Birefringence of Thin Films by Guided Waves." Presented at the Boulder Damage Symposium, November 1981 by A. Feldman.

"A Comparison of Optical and Mechanical Methods of Thickness Measurement." Presented at the East Coast Conference of the SPIE, May 5, 1982, by A. Feldman.

5.4 Scientific Meetings Attended

Boulder Damage Symposium
Boulder Colorado, September 1978

SPIE Annual Meeting
San Diego, California, August 1979

Optical Society of America Annual Meeting
Rochester, NY, October 1979

Boulder Damage Symposium
Boulder, Colorado, September 1979

American Physical Society, March Meeting
New York, NY, March 1980

Topical Conference on Basic Optical Properties of Materials
National Bureau of Standards, May 5-7, 1980

Optical Society Spring Conference on Applied Optics
Mills College, Oakland, California, June 3-6, 1980

Laser Damage Symposium
Boulder, Colorado, September 30-October 1, 1980

Optical Society of America
Chicago, Illinois, October 13-18, 1980

Second International Meeting on Photoacoustic Spectroscopy
Berkeley, California, June 22-25, 1981

Optical Society of America Annual Meeting
Kissemee, Florida, October 1981

Boulder Damage Symposium
Boulder, Colorado, November 1981

5.5 Samples of hot-forged LiF and CaF_2 were provided by John Ready of Honeywell for the examination of veiling in the material by the method of micro-Raman analysis. No Raman signal was detected indicating that the voids responsible for the veiling contained no Raman active material. The examination was performed by John Blaha of NBS.

5.6 On August 31, 1979, Dr. Haller and Dr. Feldman visited the Group of Hal Bennett at China Lake. We saw their absolute reflectometers, their talystep profilimeter and their high-vacuum systems. If particular interest was the vacuum calorimeter developed by Paul Temple for measuring small absorption coefficients in optical coatings. Dr. Temple uses a microcomputer temperature control for his instrument which has microdegree sensitivity. In fact, much of the instrumentation in the laboratory was controlled by microcomputer. Finally, we saw the diamond-turned optics facility developed by Don Decker in conjunction with a commercial manufacturer. Tolerances less than a microinch (0.025 μm) are achievable. A 6-inch diameter copper mirror can be finished to optical tolerances in 10 minutes compared to conventional methods which require several weeks.

5.7 Albert Feldman served as co-chairman of a session on Optical Materials at the SPIE annual meeting in San Diego, August 1979.

5.8 Albert Feldman visited the Air Force Weapons Laboratory and the Los Alamos National Laboratory to discuss thin film programs. A copy of the trip report is included in the Appendix.

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11. A. Feldman and E. N. Farabaugh. "Index, Thickness, and Birefringence of Thin Films by Guided Waves" in Laser Induced Damage in Optical Materials: 1981. (to be published)

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13. A. Feldman and T. Vorburger. Proceedings of the SPIE. (to be published)

7. PERSONNEL ASSOCIATED WITH PROJECT

Dr. Albert Feldman - Principal Investigator
Deane Horowitz
Roy M. Waxler
Ludwig Grabner
Theodore Vorburger

8. APPENDIX

a. NML Topical Conference on Basic Optical Properties of Materials.

b. Report of Visit to the Air Force Weapons Laboratory and Los Alamos National Laboratory by Albert Feldman.

NML TOPICAL CONFERENCE ON BASIC OPTICAL PROPERTIES OF MATERIALS

A topical conference on Basic Optical Properties of Materials sponsored by the National Measurement Laboratory of NBS in cooperation with the Optical Society of America was held May 5-7, 1980. There were 122 registrants from universities, government, and industrial research laboratories throughout the United States and more than a dozen participants from foreign countries. The purpose of the conference was to discuss the state-of-the-art in the measurement and theory of optical properties of materials of importance to advanced optical technology; that is, the conference emphasized the science of optical materials in bulk, thin film and fiber form rather than optical devices as such.

The response of the participants to both the content and organization of the Conference was highly enthusiastic. The topical areas covered, as listed in the program were: nonlinear optical properties, ultraviolet properties, infrared properties, graded index materials, inhomogeneous materials, thin films, optical fibers, planar optical waveguides, and external influences including piezo-optics, thermo-optics, and magneto-optics. Papers dealt with many aspects of optical absorption, reflection or refraction caused by electronic and phonon transitions in different regions of the optical spectrum and how these processes are affected by external influences. A significant aspect of the conference was the ever increasing variety of measurement methods for characterizing optical properties. For example, new techniques, such as integrated-optics guided-wave methods and vacuum calorimetry, and highly refined older techniques, such as spectroscopic ellipsometry and differential reflectometry, demonstrated the large advances in characterizing dielectric and metallic thin films and surfaces. The results of optical materials research will be important for many technological applications such as communications, signal processing, solar energy conversion, laser fusion, chemical spectroscopy, and optical displays.

NBS Special Publication 574 contains summaries of 62 papers presented at the conference.

Contact: Albert Feldman X3662

Report of Visit to the Air Force Weapons Laboratory and Los Alamos National Laboratory by Albert Feldman.

On June 26, 1981, I visited the Air Force Weapons Laboratory (AFWL) and the Los Alamos National Laboratory on the way home from the Second International Photoacoustics Conference, to discuss thin film programs at both these laboratories and how NBS might contribute to these programs.

Bill Lowry organized the visit to AFWL which took place in the morning. I visited with three people, LTC Ken Jungling, Major Ronald Lusk, and Allan Stuart.

Col. Jungling discussed the status of thin films relative to the damage problem. There has been no significant improvement in the damage thresholds of thin films in several years. Damage appears to occur at isolated spots on the specimen. What is needed is a fundamentally new approach to the problem. How do we formulate the basic questions? The thrust is microanalytical diagnostics of thin films. AFWL has invested in an expensive microanalytical system run by Major Lusk. At present the laboratory has only 6.2 and 6.3 funds (developmental funds). What is needed is basic research for understanding thin films in a more fundamental level. That is the purpose of the thin film initiative being proposed to AFOSR under Harry Winsor. Before support could be provided to groups outside AFWL, the proposed effect must show promise and catch the imagination of the program managers.

Col. Lusk discussed the problem of coatings for high-power HF and DF lasers. These lasers operate essentially at CW and heating in the coatings is a problem. These coatings are enhanced reflection coatings of up to 20 layers deposited on Ag plated Mo. The target absorption coefficient for coatings is 1 cm^{-1}. At present the best coatings have the following absorption coefficients at HF wavelengths: Al_2O_3-15 cm^{-1}, Si-45 cm^{-1}, SiO-5 cm^{-1}, ZnS-7 cm^{-1}, ZrO_2 - unstable. Polycrystalline material is considered poor. What is wanted is single crystal coatings or dense amorphous coatings. The coating thicknesses are about one quarter wave. AFWL has just acquired a PHI Model 590 instrument which contains Scanning Auger, SIMS, and ESCA with the possibility of electron microscopy with 2000 Å resolution. The system has a UTI residual gas analyzer and an Ar^+ source for the SIMS. Major Lusk expressed the view that the AFOSR thin film initiative will support mainly inhouse AFWL thin film programs. It is expected that sometime in the fall, laboratories will be invited to make presentations of proposed thin film research with regard to the new AFOSR program. If the program is approved it will take place in FY83.

Allan Stuart has been attempting to make photoacoustic measurements for detecting precusors to laser damage. As yet, he has been able to get a photoacoustic signal only one shot before damage. He has been working with a Nd:YaG laser system. Dr. Stuart was very helpful in suggesting equipment we might use in our photoacoustic measurements.

In the afternoon, I visited Los Alamos National Laboratory where I talked with Brian Newnam, Dave Edwards, and Norman Barnes.

Dr. Newnam expressed views similar to the views expressed at AFWL. Columnar structure in thin films is bad because impurities can diffuse between the columns. Amorphous films would be desirable. He had been doing damage studies on UV coatings for the KrF laser at 248 nm, the XeCl laser at 308 nm and the XeF laser at 350 nm. However, one third of his DOE funding has been cutback, although DARPA funding has continued. The DARPA program manager is Joseph Friebele. Dr. Newnam is presently working mainly on a free electron laser.

Dr. Newnam expressed the view that electron-beam deposition has reached its limit as far as reduction in damage thresholds. Sputtering has uniformity problems. Ion beam deposition appears to have good promise. It is being done at Litton, Honeywell and the University of New Mexico. Ion beam deposition relies on direct momentum transfer rather than on thermal energy. The particles come off with greater velocity and produce dense, low-scatter, low-loss films. The method works well with oxides but its utility with fluorides is not yet demonstrated. Fluorides are subject to dissociation.

Another new method has been magnetron sputtering. This method appears to produce superior Si coatings.

I mentioned our use of coevaporation to produce amorphous coatings. He thought it might be a good method provided the refractive index is not modified excessively.

Dave Edwards has an interest in antireflection coatings for 16 μm. He has addressed the problem of deposition of PbF_2 on CdSe and CdTe. Stoichiometry is a problem due to heating of the substrates which leads to their decomposition. It would be better if films could be deposited at room temperature. Peter La Delfe, at Los Alamos is looking at the problem. He is studying the deposition problem looking at grain size, effect of substrate conditions, and ultimately damage thresholds. At present the wavelengths of interest are 16 μm, 10.6 μm and 0.308 μm. They are interested in AR coatings, reflecting coatings and dichroic mirrors (mirrors that reflect at one wavelength and that transmit at another). Dr. Edwards asked, what would be the use rate of our facility, assuming he wanted some work done. I replied that it would be negotiated on the basis of a contract. At present his work is being done in-house although he will keep us in mind.

I spoke to Norman Barnes. He is not involved with thin films, but has recently completed dn/dT measurements on ADP and some of its isomorphs.

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8